ERDC/CERL TR-01-38

US Army Corps of Engineers®
Engineer Research and Development Center

Site Evaluation for Application of Fuel Cell Technology

934th Airlift Wing, Minneapolis, MN

Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

March 2001

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Foreword

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DOD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

This report documents work done at 934th Airlift Wing, Minneapolis, MN. Special thanks is owed to the 934th Airlift Wing points of contact (POCs), Mehrdad Sadeghi, Philip Winkels, and Jerome La Londe, for providing investigators with access to needed information for this work. The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael J. Binder. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations, CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the

owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at 934th Airlift Wing, Minneapolis, MN along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (see Table 1).

Objective

The objective of this work was to evaluate 934th Airlift Wing as a potential location for a fuel cell application.

Approach

On 13 and 14 September 1994, Science Applications International Corporation (SAIC) visited the 934th Tactical Air Group (the site) to investigate the potential installation for a 200 kW phosphoric acid fuel cell. This report summarizes the information collected during the visit as well as conceptual fuel cell installation layout and estimated operating savings associated with the fuel cell installation. The Appendix to this report contains a copy of the site evaluation form filled out at the site

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Fort Bliss, TX	TR 01-13
Fort Eustis, VA	TR 00-17
Fort Huachuca, AZ	TR 00-14
Fort Richardson, AK	TR 00-Draft
Picatinny Arsenal, NJ	TR 00-24
Pine Bluff Arsenal, AR	TR 01-15
U.S. Army Soldier Systems Center, Natick, MA	TR 00-Draft
U.S. Military Academy, West Point, NY	TR 00-Draft
Watervliet Arsenal, Albany, NY	TR 00-Draft
911th Airlift Wing, Pittsburgh, PA	TR 00-18
934th Airlift Wing, Minneapolis, MN	TR 00-19
Barksdale Air Force Base (AFB), LA	TR 01-29
Davis-Monthan AFB, AZ	TR 00-23
Edwards AFB, CA	TR 00-Draft
Kirtland AFB, NM	TR 00-Draft
Laughlin AFB, TX	TR 00-Draft
Little Rock AFB, AR	TR 00-Draft
Nellis AFB, NV	TR 01-31
Westover Air Reserve Base (ARB), MA	TR 00-20
Construction Battalion Center (CBC), Port Hueneme, CA	TR 00-16
Naval Air Station Fallon, NV	TR 00-15
Naval Education Training Center, Newport, RI	TR 00-21
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 00-Draft
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Subase New London, Groton, CT	TR 00-Draft
U.S. Naval Academy, Annapolis, MD	TR 00-22
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mile	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

The 934th Tactical Air Group is located in Minneapolis, MN at the Minneapolis-St. Paul International Airport. This facility serves as a reserve base for the Air Force and the Navy. The Site consists of approximately 40 buildings including housing, administrative, cafeteria, central energy plant and other support use buildings. Temperatures for this area range from a design temperature of –16 °F in the winter to a design temperature of 89 °F in the summer. These temperatures do not reflect a correction for wind or humidity. Historical weather data for the airport also shows 6728 heating degree days per year and 662 cooling degree days per year. The Site normally has approximately 350 people working Monday through Friday from 7:00 am to 4:00 pm. The Site functions as a reserve facility for the military and will typically see a high occupancy 1 week per month and on weekends which can reach 1500 people.

The electrical output from the fuel cell (200 kW) is lower than the lowest demand for the Site, which was estimated to be 250 kW. The electric utility, NSP, has stated some concern for the potential for electrical feed back to the grid. This issue will need to be addressed. Peak electrical demand for the Site from January 1993 to July 1994 ranged from 840 kW to 1280 kW. The Site has one master electric meter and approximately three submeters for tenants. The central plant has an existing diesel backup generator with an electrical capacity of 150 kW. The peak electrical load for the central plant is estimated to be 200 kW. The major components of this load are pumps and a 60 HP air compressor. There are three options for heat recovery from the fuel cell. The first is the make up water and condensate water for the central plant. The second thermal load is the hot water for the cafeteria. The third potential for thermal use is domestic hot water (DHW) for two dormitories.

Site Layout

Figure 1 illustrates the proposed location for the fuel cell between buildings 812 and 814. Building 812 is the central plant. Although three thermal sources were evaluated, this proposed location would accommodate all investigated interfaces. The central plant houses five boilers, an air compressor, pumps and ancillary equipment. The central plant is approximately 55 years old. The area for the fuel cell is a flat grass area between the buildings.

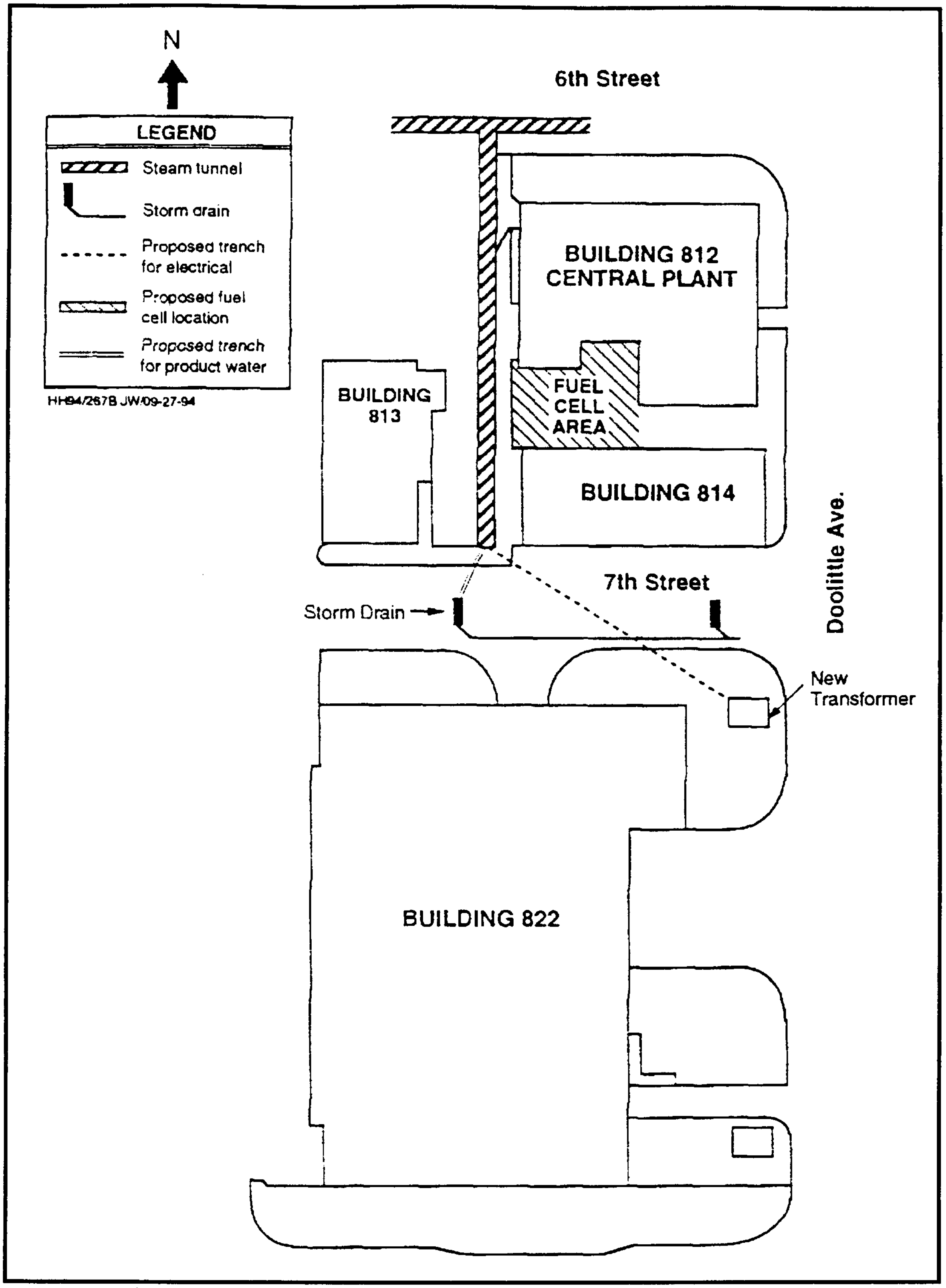

Figure 1. 934th Tag proposed fuel cell location.

Running throughout the Site is an underground steam tunnel system. Part of the tunnel runs near the proposed fuel cell location and can be used to minimize trenching for electrical interfacing to the transformer and piping for the product water drain.

Electrical System

The existing system has a 13,800/480 volt, 100 kVa transformer located on the east side of building 822. This transformer is too small to be used as an electrical interface for the fuel cell. The Site will require the installation of a new transformer that shall be 1380/480 volt rated at 300 kVa. To reduce the amount of trenching, the proposed location for the new transformer is the northeast corner of building 822 where there are other existing electrical enclosures. This location is shown in Figure 1. Minnegasco is coordinating the purchase and installation of the new transformer with assistance from NSP.

Steam/Hot Water System

The central plant has five steam boilers and supplies steam to the Site through the underground steam tunnels. The steam loop interfaces with the individual building loads through interface heat exchangers to provide space heating and domestic hot water. A 5000-gal storage tank in the central plant is used for boiler makeup and condensate return.

Space Heating System

The Site's space heating is provided by the central plant boilers and steam loop.

Space Cooling System

The buildings have individual cooling systems. The Site has no absorption chillers.

Fuel Cell Location

A flat grassy area between buildings 812 and 814 is the proposed location for the fuel cell. This area is depicted in Figure 2 with approximate dimensions. The fuel cell would be located in close proximity to the central plant and be able to take advantage of the steam tunnel to reduce trenching for interface connections. The end of the tunnel to the closest storm drain is approximately 10 to 15 ft. This would be used for the disposal of excess product water. The proposed location of the new transformer will require trenching of approximately 75 ft from the end of the steam tunnel. Consideration needs to be made for setting the fuel cell on site to ensure that the weight of the delivery truck, crane or other equipment used for placing the fuel cell does not exceed the allowable loading on any tunnel.

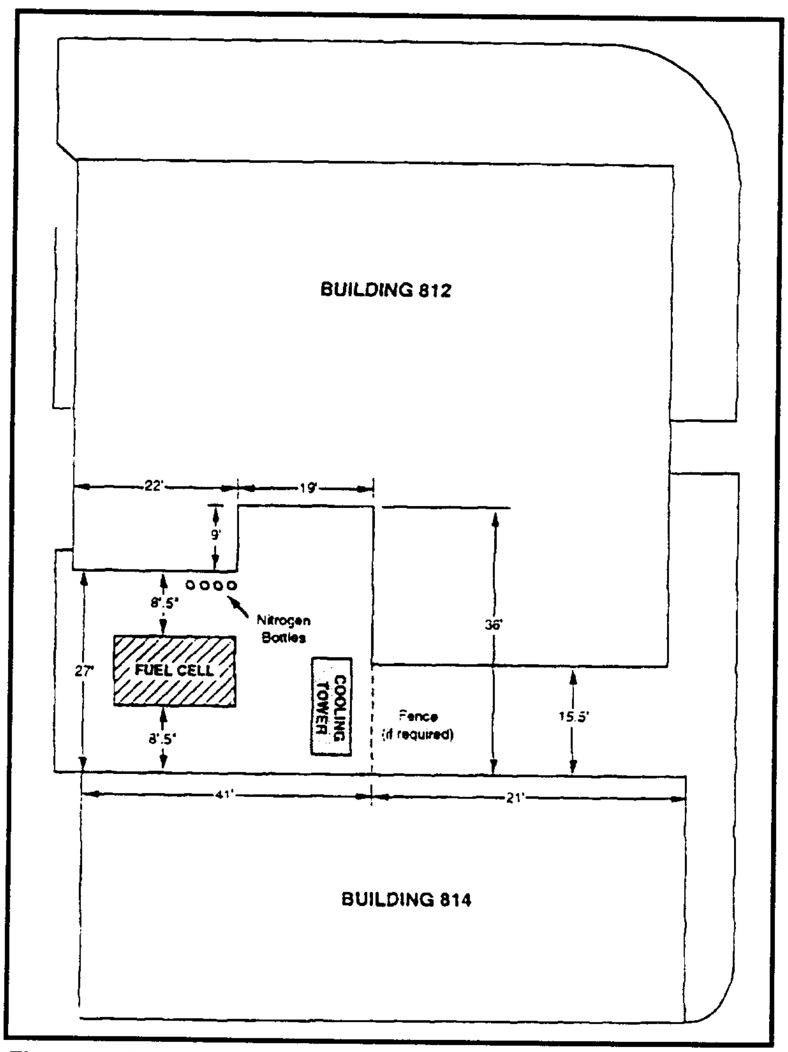

Figure 2. Fuel cell layout.

Figure 3 shows the location of the proposed fuel cell along with the required interfaces. The thermal connection to the boiler makeup and condensate return storage tank in the central plant will run through the south wall of the central plant. The tank is located immediately on the inside wall. The total distance from the fuel cell to the tank will be approximately 20 to 25 ft. This tank is atmospheric so the interface would need to be piped such that water would be pumped from the bottom of the tank through the fuel cell and back into the top of the tank. There is an existing 2-in. gate valve that can be used for the bottom connection of the tank. Figure 4 presents a conceptual detail of the thermal interface. The electrical interface would require running conduit to the steam tunnel and then south to the end of the tunnel. From the end of the tunnel, a 75-ft trench will be required to the location of the new transformer. The piping for the product water would follow a similar path as the electrical connection down the steam tunnel and then trenched to interface with the existing storm drain (10 to 15 ft). The locations of these trenches are shown in Figure 1. The gas connection can be made at the gas manifold in the central plant. The cooling tower should be located near the narrow area between buildings 812 and 814 to allow cool air to be pulled from both sides of the buildings.

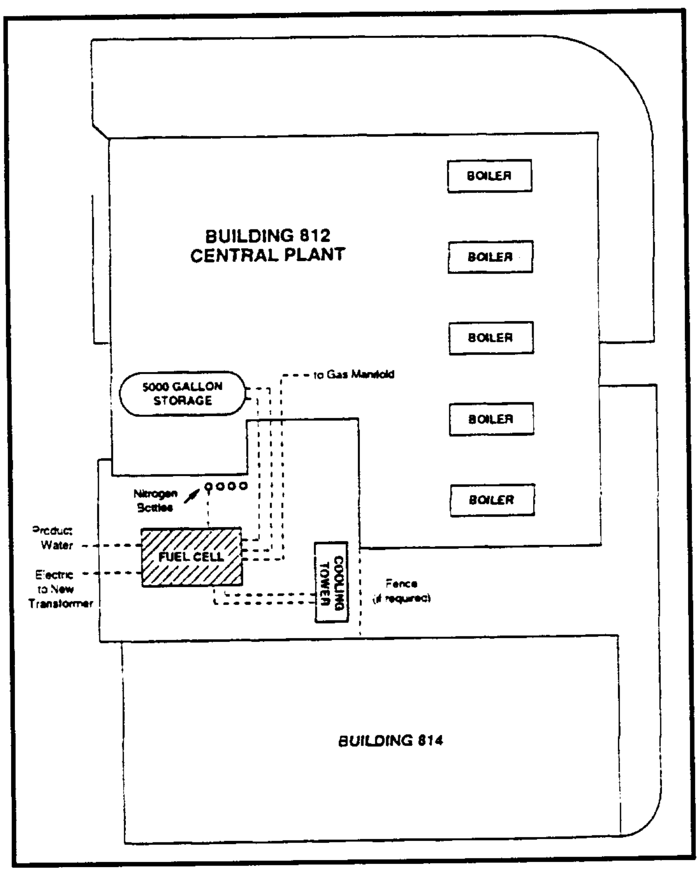

Figure 3. Fuel cell interface.

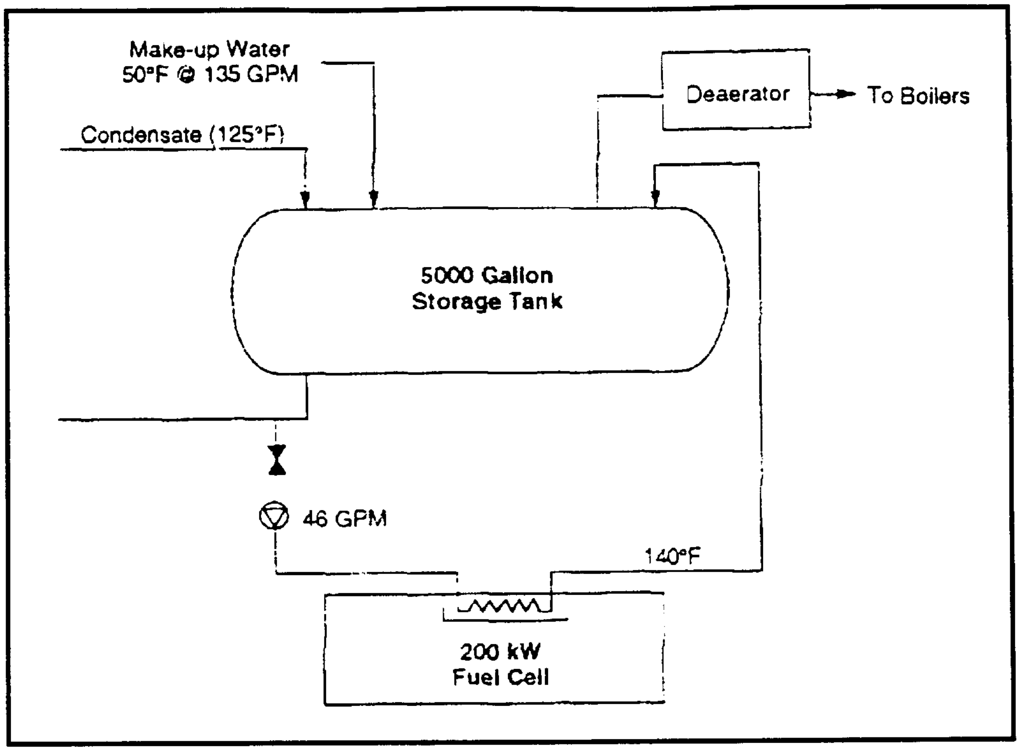

Figure 4. Fuel cell thermal interface detail.

Fuel Cell Interfaces

It is recommended that the fuel cell be electrically connected to the 480 volt side of the new 13,800/480 volt 300 kVa transformer. The average peak demand for the Site from January 1993 through June 1994 is 1010 kW and the estimated minimum demand for the Site is approximately 250 kW. It is anticipated that the fuel cell capacity will not exceed the Site demand at any time. The average electrical demand for the central plant is estimated to be 150 kW. The suggested interface is to pass all fuel cell output through the transformer for distribution. If the Site decides to use the fuel cell for backup, direct interface to the central plant could be implemented.

Three thermal interfaces were evaluated. These are: (1) Boiler makeup and condensate return, (2) Dining hall hot water for kitchen, and (3) Domestic hot water for two dormitories. The Site has an extensive heating load due to the cold and long winters. The heating season lasts for 8 months of the year (October to May). The thermal loads associated with the dining hall and the dormitories would provide thermal utilization during the 4 nonheating months. The thermal usage for the three options are:

1. *Boiler makeup and condensate return storage.*

The storage tank has a volume of 5000 gal and stores water for the boiler makeup and condensate return. The condensate return is estimated to be 125 °F. Using values from the operator log, the average rate of makeup water into the storage tank is 135 gal/hr and the temperature is estimated to be 50 °F. Assuming that for an hour period that the storage tank (which operates just over half full) contains 3000 gal of water at 125 °F and 135 gal at 50 °F, the average tank temperature would be 120 °F. In this scenario, it was assumed that the fuel cell would be capable of heating the 120 °F water to 140 °F at 46 gpm. The thermal utilization rate would be:

46 gal/min * 60 min/hr * 1 Btu/lb °F * 8.33 lb/gal * (140 – 120 °F) =
460,000 Btu/hr

The boiler gas meter data indicates that the boiler load is large enough to use 100 percent of the fuel cell thermal output from October to May. However, the temperature requirements reduce the fuel cell output from 700,000 Btu/hr to 460,000 Btu/hr. The thermal utilization for the fuel cell is 39 percent, with a 90 percent fuel cell capacity factor.

((460,000 Btu/700,000 Btu)*(8 months/12 months)*90%).

2. *Dining hall hot water for kitchen.*

The thermal load for the kitchen is based on 250 meals per serving for three servings per day (breakfast, lunch and dinner). Using numbers from the 1991 ASHRAE Handbook, a typical full service restaurant or cafeteria will have an average hot water consumption of 2.4 gal/meal/day. To meet this load, a hot water storage tank will be required. The volume of hot water to meet one day's load is 1800 gal (2.4 gal/meal * 250 meals/serving * 3 servings/day). Assuming a 30 percent standby loss, the storage required for this thermal load would be 2600 gal. The thermal utilization from the fuel cell would be:

2,600 gal/day * 24 hours/day*1 Btu/lb °F * 8.33 lb/gal * (180 – 60 °F) =
108,000 Btu/hr

Note that this thermal load will only benefit the fuel cell thermal utilization during the summer months. The fuel cell thermal utilization for this load is 5 percent, with a 90 percent fuel cell capacity factor.

3. *Domestic hot water for two dormitories.*

The demand for hot water is based on an estimated occupancy in the dormitories of 100 people each. Using numbers from the 1991 ASHRAE Handbook, the daily average hot water consumption per occupant is 12 gal. To meet this load, a hot water storage tank will be required. The volume of hot water to meet 1 day's load is 2400 gal (12 gal/day*200 people). Assuming a 30 percent standby loss, the storage required for this thermal load would be 3500 gal. The thermal utilization from the fuel cell would be as follows:

3,500 gal/day * 24 hours/day*1 Btu/lb °F * 8.33 lb/gal * (140 – 60 °F) =
97,000 Btu/hr

Note that this thermal load will only benefit the fuel cell thermal utilization during the summer months. The fuel cell thermal utilization for this load is 5 percent, with a 90 percent fuel cell capacity factor.

3 Economic Analysis

Energy savings were calculated based on projected energy utilization of fuel cell electrical and thermal output. Site energy rates were used as the basis for calculating fuel cell energy savings.

The Site electricity is supplied by Northern States Power. NSP's rates are summarized in Table 2. Electric bills were obtained for July 1993 through June 1994 and are summarized in Table 3. The site is on a General Service rate with energy and demand charges being separated for winter and summer. The winter rates are for the months of October through May and the summer rates are for June through September. Since the Site purchases electricity at the primary voltage, they receive a year round discount of \$0.95/kW and \$0.0005/kWh. The bills show that the average electric costs for winter have been \$5.46/kW and \$0.0305/kWh and the costs for summer have been \$7.72/kW and \$0.0310/kWh.

The Site purchases natural gas from Minnegasco. Minnegasco is proposing to put the fuel cell on a dual fuel rate that has averaged \$2.46/DKTherm (\$2.46/MBtu) over the last 56 months. Table 4 lists the calculations of operating the fuel cell on this rate with a fuel cell capacity factor of 90 percent over the period of July 1993 through June 1994. The average gas rate for this 1-year period was \$2.61/MBtu). Table 5 summarizes the electrical cost reduction of the fuel cell operating at the same conditions and time period.

Table 2. Northern States Power general service power electrical rate.

Service	**Charge**	
Customer Charge per Month	\$21.65	
	Oct - May	June - Sept
Services at Secondary Voltage		
Demand Charge per Month (All kW - per kW)	\$6.61	\$9.25
Energy Charge per kWh	\$0.0310	
Energy Charge Credit per Month (All kWh in Excess of 400 Hours Times the Billing Demand)	\$0.0070	
Voltage Discounts per Month	***January***	***December***
	Per kW	*Per kWh*
Primary Voltage	\$0.95	\$0.0005

Table 3. Electrical bill summary, 934th Tactical Air Group Minneapolis, MN.

Month	Days	Billed Demand (kW)	Demand Rate ($/kW)	Demand Amount ($)	Energy Usage (kWh)	Energy Rate ($/kWh)	Energy Amount (CS)	Total Charges (CS)
June 1994	30	1,213	$8.31	$10,080	362,600	$0.0308	$11,771	$21,257
May 1994	31	887	$5.66	$5,020	383,600	$0.0304	$11,657	$16,677
April 1994	30	1,191	$5.66	$6,741	404,600	$0.0306	$12,366	$19,107
March 1994	31	938	$5.46	$5,121	389,200	$0.0299	$11,622	$16,743
February 1994	28	1,064	$5.46	$5,809	410,200	$0.0301	$12,332	$18,141
January 1994	31	1,054	$5.46	$5,754	548,800	$0.0302	$16,575	$22,329
December 1993	31	915	$5.46	$4,996	424,200	$0.0298	$12,625	$17,621
November 1993	30	935	$5.46	$5,105	348,600	$0.0306	$10,684	$15,789
October 1993	31	883	$7.26	$6,411	432,600	$0.0315	$13,639	$20,050
September 1993	30	1,280	$7.72	$9,882	485,800	$0.0316	$15,333	$25,215
August1993	31	1,173	$7.72	$9,055	413,000	$0.0313	$12,943	$21,998
July1993	31	1,077	$7.72	$8,314	364,000	$0.0304	$11,067	$19,381
Total	**365**	**12,610**		**$82,288**	**4,967,200**		**$152,014**	**$234,302**
Average			**$6.45**			**$0.0306**		

Table 4. Fuel cell gas costs, 934th Tactical Air Group Minneapolis, MN.

Month	Days	Gas Rate ($/MBtu)	Fuel Cell Gas (Therm)	Fuel Cell Gas Cost ($)
June 1994	30	$2.15	122,868	$2,642
May 1994	31	$2.34	126,964	$2,971
April1994	30	S2.46	122,868	$3,023
March 1994	31	$2.77	726,964	$3,517
February 1994	28	$2.77	114,677	$3,177
January 1994	31	$2.69	126,964	$3,415
December 1993	31	$2.91	126,964	$3,695
November 1993	30	$2.49	122,868	$3,059
October 1993	31	$2.70	126,964	$3,428
September 1993	30	$2.87	122,868	$3,526
August 1993	31	$2.63	726,964	$3,339
July 1993	31	$2.53	126,964	$3,212
Total	**365**		**1,494,894**	**$39,004**
Average		**$2.61**		

Inputs:	Fuel Cell Capacity (kW)	200
	Fuel Cell Electrical Efficiency	36%
	Fuel Cell Capacity Factor	90%

Table 5. Electrical cost reduction, 394th Tactical Air Group Minneapolis, MN.

Month	Days	Demand Rate ($/kW)	Energy Rate (S/kWh)	Demand Savings ($)	Energy Reduction (kWh)	Energy Savings ($)
June 1994	30	$8.31	$0.0308	$1,662	129,600	$3,993
May1994	31	$5.66	$0.0304	$1,132	133,920	$4,070
April 1994	30	$5.66	$0.0306	$1,132	129,600	$3,961
March 1994	31	$5.46	$0.0299	$1,092	133,920	$3,999
February 1994	28	$5.46	$0.0301	$1,092	120,960	$3,636
January1994	31	$5.46	$0.0302	$1,092	133,920	$4,045
December1993	31	$5.46	$0.0298	$1,092	133,920	$3,986
November 1993	30	$5.46	$0.0306	$1,092	129,600	$3,972
October1993	31	$7.26	$0.0315	$1,452	133,920	$4,222
September1993	30	$7.72	$0.0316	$1,544	129,600	$4,090
August1993	31	$7.72	$0.0313	$1,544	133,920	$4,197
July1993	31	$7.72	$0.0304	$1,544	133,920	$4,072
Total	**365**			**$15,470**	**1,576,800**	**$48,243**
Average		**$6.45**	**$0.03**			
Inputs: Fuel Cell Size: 200 kW Capacity Factor: 90%						

The fuel cell savings associated with the use of the fuel cell thermal output is calculated for the three thermal options discussed above, based on the following assumptions:

1. *Boiler makeup and condensate return storage*

    Assume a boiler efficiency of 75 percent

    Assume Fuel Cell Capacity Factor of 90 percent

    Fuel Cell Thermal Output Rate is 460,000 Btu/hr

    Months of Heating Load is 8 (5,840 hr/yr)

    Average Gas Rate is $0.261/Therm

    Savings: 32,237 Therms/yr * $0.261/Therm = $ 8,414/yr

2. *Dining hall hot water for kitchen*

    Assume a boiler efficiency of 75 percent

    Assume Fuel Cell Capacity Factor of 90 percent

    Fuel Cell Thermal Output Rate is 108,000 Btu/hr

    Months of Heating Load is 4 (2,920 hr/yr)

Average Gas Rate is \$0.261/Therm

Savings: 3,784 Therms/yr * \$0.261/Therm = \$ 988/yr

3. *Domestic hot water for two dormitories*

Assume a boiler efficiency of 75 percent

Assume Fuel Cell Capacity Factor of 90 percent

Fuel Cell Thermal Output Rate is 97,000 Btu/hr

Months of Heating Load is 4 (2,920 hr/yr)

Average Gas Rate is \$0.261/Therm

Savings: 3,399 Therms/yr * \$0.261/Therm = \$ 887/yr

Potential Annual Cost Savings Displaced Energy Costs: \$ 48,243

Displaced Demand Costs: \$ 15,470

Boiler makeup and condensate return storage \$8,414

Dining hall hot water for kitchen: \$988

Domestic hot water for two dormitories: \$887

Fuel Cell Fuel Cost

Natural Gas Costs: \$ 39,004

Thus, the total estimated annual fuel cell savings including thermal use ranges from \$33,123 (thermal=central plant only) to \$34,998 (all three thermal loads). Table 6 presents a summary of this analysis, including a sensitivity to demand charge savings.

The thermal interface to the central plant is relatively simple and should not be a significant impact on the installation cost. The thermal interface for the dining hall and the dormitories will require a 5000-gal storage tank for holding 180 °F water. The water would then need to mixed down to 140 °F for the DHW. Piping to the two facilities will require approximately 300 ft to the dining hall and 500 ft to the dormitories. The estimated cost for the tank, piping and controls is \$12,000 to \$16,000. This would result in a simple pay back of 6.8 to 9.0 years.

The analysis is a general overview of the economics. For the first 5 years, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net savings. Since load profile data were not available, energy savings could vary depending on actual electrical and thermal utilization.

Table 6. Economic savings of fuel cell design alternatives.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat.Gas Cost	Net Savings
A - Max. Thermal	90%	100%	1,576,800	7,357	$63,713	$19,202	$39,017	$43,898
A - Central Plant + Dorms + kitchen	90%	54%	1,576,800	3,920	$63,713	$10,231	$39,017	$34,927
A - Central Plant Only	90%	44%	1,576,800	3,234	$63,713	$8,441	$39,017	$33,137
B - Max. Thermal	90%	100%	1,576,800	7,357	$55,978	$19,202	$39,017	$36,163
B - Central Plant + Dorms + kitchen	90%	54%	1,576,800	3,920	$55,978	$10,231	$39,017	$27,192
B - Central Plant Only	90%	44%	1,576,800	3,234	$55,978	$8,441	$39,017	$25,402
C - Max. Thermal	90%	100%	1,576,800	7,357	$48,243	$19,202	$39,017	$28,428
C - Central Plant + Dorms + kitchen	90%	54%	1,576,800	3,920	$48,243	$10,231	$39,017	$19,457
C - Central Plant Only	90%	44%	1,576,800	3,234	$48,243	$8,441	$39,017	$17,667

Assumptions:

Input Natural Gas Rate: $2.61 /MBtu

Displaced Thermal Gas Rate: $2.61 /MBtu

Displaced Electricity Rate: 3.06 Cents/KWh

Displaced Demand Rate: General Service Rate

Fuel Cell Thermal Output: 700,000 Btu/hour

Fuel Cell Electrical Efficiency: 36%

Seasonal Boiler Efficiency: 75%

CASE A: full fuel cell demand savings

CASE B: 50% of full fuel cell demand savings

CASE C: zero fuel cell demand savings

4 Conclusions and Recommendations

This study concludes that the central plant at the 934th TAG is a good location for an advanced energy fuel cell. The Site has an ideal space for a relatively straightforward installation. The proposed location between buildings 812 and 814 is flat and can accommodate the clearances required for fuel cell placement. As a test site, this installation will provide valuable information on fuel cell performance in a cold climate. Site personnel and Minnegasco have expressed enthusiasm about installing a fuel cell at this location.

The recommended thermal interface for the installation is the storage tank for the central plant. Although this report presents savings for interfacing with the dining hall and dormitories, load profiles and occupancy rates were not available and had to be estimated using ASHRAE information. Also given, that the benefit to the fuel cell is only realized for 4 months of the year, it is not recommended to incorporate these interfaces for the installation.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **934th Tactical Air Group**
Location: **Minneapolis, MN**
Contacts: **Mehrdad Sadeghi**

1. Electric Utility: **Northern States Power**
   Contact:
   Rate Schedule: **General Service**

2. Gas Utility: **Minnegasco**
   Contact: **Jim Radford**
   Rate Schedule: **Dual Fuel**

3. Available Fuels: **Natural Gas/Fuel Oil**
   Capacity Rate:

4. Hours of Use and Percent Occupied:

Weekdays	5	Hrs.	9
Saturday		Hrs.	
Sunday		Hrs.	

5. Outdoor Temperature Range: Design Temperatures: **160 °F to 89 °F**

6. Environmental Issues: **None.**

7. Backup Power Need/Requirement: **150 kW diesel backup generator on site.**

8. Utility Interconnect/Power Quality Issues: **The fuel cell will be disconnected from grid if Base load drops below 30 kW**

9. On-site Personnel Capabilities: **Gas Company personnel will perform maintenance.**

10. Access for Fuel Cell Installation: **Access is tight, but adequate. Steam tunnel should be noted for offloading.**

11. Daily Load Profile Availability: **None**

12. Security: **No fence required**

Site Layout

Facility Type: **Central Boiler Plant**

Age: **55 Years**

Construction:

Square Feet: **~5500 sq ft**

See Figure 3

Electrical System

Service Rating: **13,800/480 volt, 300 kVa transformer.**

Electrically Sensitive Equipment:

Largest Motors (hp, usage):

Grid Independent Operation?:

Steam/Hot Water System

Description: **Central System; 5 Boilers**

System Specifications:

Fuel Type:

Max Fuel Rate:

Storage Capacity/Type: **5000-gal storage, vented.**

Interface Pipe Size/Description: **2-in. valve bottom on tank; 3-in. line tank to dearator**

End Use Description/Profile:

Kitchen: 7 days/week 200 meals, 3 times/day
Dormitories: 190 rooms
35% occupancy; weekdays
100% occupancy, weekends

Space Cooling System

Description: **no absorption chillers Air Conditioning Configuration:**

Type:

Rating:

Make/Model:

Seasonality Profile:

No data available

Space Heating System

Description: **Heat exchangers in buildings**

Fuel:

Rating:

Water supply Temp: **225 °F (dearator)**

Water Return Temp: **125 °F**

Make/Model:

Thermal Storage (space?): **5000 gal**

Seasonality Profile: **Heating season: 9/15 to 5/15**

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4. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) has actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and has selected and evaluated application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers for 29 of 30 commercially available fuel cell power plants and their thermal interfaces installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at the 934th Airlift Wing, Minneapolis, MN, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

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